Environmental monitoring & safeguards: Reinforcing analytical capabilities

The IAEA is planning a specially designed "clean" laboratory for analyzing environmental samples from safeguards inspections

by
David Donohue, Stein Deron, and Erwin Kuhn

Radiometric monitoring of rivers, streams, sediments, and other environmental pathways has become an important element of the IAEA's long-term verification of the nuclear programme in Iraq. At the same time, a number of countries voluntarily are participating in IAEA field trials to demonstrate the capability of environmental monitoring techniques for the detection of nuclear activities. The techniques allow for chemical and isotopic analysis of minute samples of water, soil, biota, and other environmental materials to detect "nuclear signatures" that are specific to certain types of facilities and operations.

The analysis of collected environmental samples and measurements is a highly specialized and exacting discipline, one that requires suitably equipped and designed facilities and a high level of analytical expertise. Environmental samples taken in Iraq, for example, have been measured with state-of-the-art analytical methods in specialized laboratories in several IAEA Member States; the detection limit for uranium or plutonium by these methods is around 10 million atoms.

For its part, the IAEA has established an extensive in-house capability for performing analytical chemistry measurements, whether in support of programmes for technical co-operation, human health, nuclear safety, or safeguards. Expertise in the measurement of radioactive elements in the environment exists at the Physics, Chemistry and Instrumentation Laboratory at the IAEA's Seibersdorf Laboratories; the Isotope Hydrology Laboratory at IAEA headquarters in Vienna; and the IAEA's Marine Environment Laboratory in Monaco. In addition, many qualified laboratories in IAEA Member States provide analytical services for safeguards purposes or participate in exercises to characterize materials for the IAEA's Analytical Quality Control Service.

Building upon this experience, the IAEA is moving to establish a "clean" laboratory at the site of its research laboratories in Seibersdorf, Austria, specifically dedicated to the analysis of environmental samples and measurements for safeguards purposes. The laboratory will serve to augment services being provided by the Safeguards Analytical Laboratory, which the IAEA set up in the 1970s and today handles more than 1000 samples of uranium, plutonium, and other types of nuclear material each year.

Why a "clean laboratory" is needed

Why does the IAEA need a special clean laboratory? There are five basic reasons:

- Experience with the inspections of the IAEA Iraq Action Team has shown the importance of environmental sampling and analysis for the detection and elaboration of undeclared nuclear activities, and the indispensability of high-quality analytical capabilities. One of the main limitations on the use of ultra-sensitive monitoring techniques is maintaining the integrity of the sample — that is, preventing its contamination with spurious materials which could lead to disastrously wrong conclusions. This requires that the IAEA apply stringent measures to ensure that clean sampling materials are used and that the post-inspection handling and analysis of the samples is performed under conditions of extraordinary cleanliness. The IAEA faces a continuing need to apply such techniques in its ongoing long-term monitoring programme in Iraq under UN Security Council Resolution 715.

In addition, the IAEA has the right under INFCIRC/153-type safeguards agreements

Mr. Deron is Head of the Safeguards Analytical Laboratory (SAL) at the IAEA Seibersdorf Laboratories, and Mr. Donohue is a SAL staff member. Mr. Kuhn is a staff member of the IAEA Department of Safeguards.

(those concluded pursuant to the Treaty on the Non-Proliferation of Nuclear Weapons) to request special safeguards inspections in order to exclude the existence of undeclared nuclear activities. Environmental sampling and ultra-sensitive analysis techniques represent an essential part of such special inspections.

● Whenever a State enters into a comprehensive safeguards agreement with the Agency, the IAEA must carry out ad hoc inspections to verify the correctness and completeness of the State's initial declaration. This has been done recently in South Africa and remains under way in the Democratic People's Republic of Korea. Similar work will soon start in Argentina and Brazil under the quadripartite safeguards agreement and in several republics of the former Soviet Union which have signed comprehensive safeguards agreements, such as Kazakhstan.

In a number of instances, environmental monitoring has already been used with the approval of State authorities, and it is expected that this technique will continue to be used in ad hoc inspections as a confidence-building measure. This underscores the need to derive reliable conclusions from environmental monitoring measurements, and to prevent contamination of samples.

● In 1993, the IAEA Director General's Standing Advisory Group on Safeguards Implementation (SAGSI) presented its recommendations for strengthening the safeguards system and making it more effective and efficient. The IAEA has responded to these recommendations by formulating the safeguards programme known as "93+2" to study options for improving routine safeguards implementation. One task involves an evaluation of environmental monitoring techniques for the detection of undeclared nuclear activities at declared or unknown sites. There is a strong possibility that some form of environmental sampling and analysis will be incorporated into routine safeguards implementation, which could result in a large number of environmental samples being taken and handled by the IAEA. Handling such a large number of samples without cross-contamination will be a challenging task. In addition, efficient use of the existing analytical capacity in the Agency or in Member State laboratories will require the application of rapid, sensitive, and selective screening techniques to select those samples which warrant further analysis.

● It would not be cost-effective for the IAEA to duplicate the specialized analysis capabilities which exist in Member States. The best use of these laboratories must be made by distributing among them the environmental samples coming from ad hoc, special, or routine safeguards inspections. It is always desirable to submit replicate samples to different laboratories as a check on the accuracy of their results. This quality assurance function involves a number of other activities. These include the preparation and distribution of reference or control samples; the certification of clean sampling materials; and the proper documentation of sampling and analytical procedures. The IAEA cannot afford to delegate this quality assurance function. In order to execute it properly, there must be in-house analytical capabilities which are of comparable performance to those in national laboratories. This need not be a duplication of their efforts and can certainly not compete in terms of sample throughput. Rather, the IAEA would serve as a referee laboratory which is competent to control and assure the quality of the overall service.

Receipt of safeguards inspection material at the IAEA's Safeguards Analytical Laboratory.

● Finally, it should be stressed that the IAEA requires an *independent* analytical capability for these environmental or special samples. In many cases, the identity of the samples, their origin, and the inspector's knowledge of the sampling site must be factored into the scheme of analysis. This, as well as the need for rapid feedback to the inspectors, requires an in-house analytical capability which can provide the needed buffer between the Department of Safeguards and the Member State laboratories in order to maintain the safeguards confidentiality of the results.

What will the clean laboratory do?

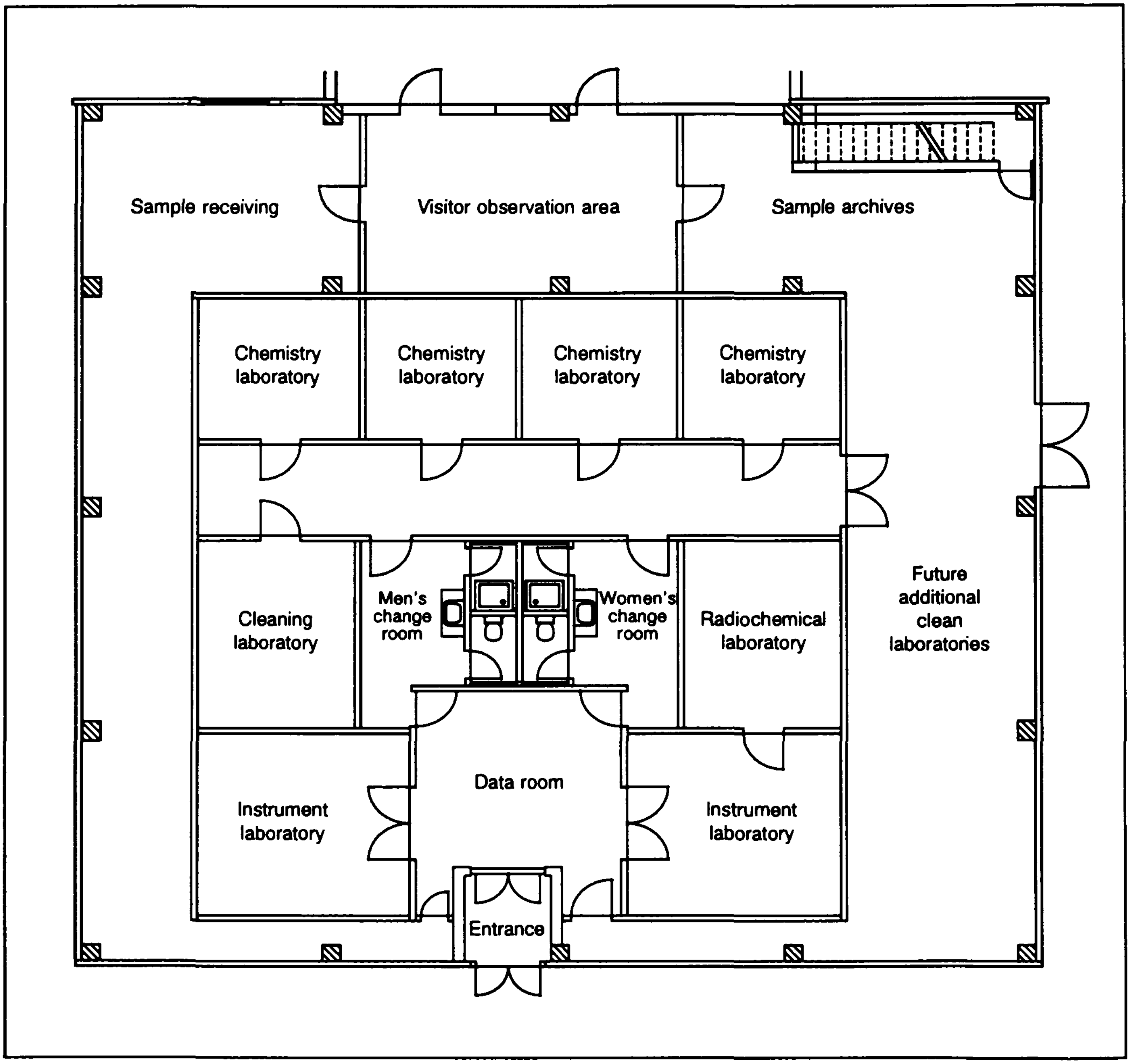
The design of the clean laboratory must provide for a number of activities, including:

● personnel access involving complete clothing change;

● transfer of samples, preliminary cleaning and replacement of the outer packaging;
● splitting, repackaging, and archival storage of samples;
● preliminary screening of samples by non-destructive techniques such as alpha counting, gamma spectrometry, or X-ray fluorescence spectrometry to determine the gross radioactivity and major elements present.
● chemical treatment of samples to concentrate analytes of interest such as uranium and plutonium. Sample types to be treated include water, soil, sediment, vegetation, biota, and swipes. High-purity isotopic spikes may be added to allow quantification of the important elements by isotope dilution mass spectrometry.
● measurement of the isotopic composition and concentration of uranium, plutonium, and other elements by thermal ionization mass spectrometry, equipped with ion-counting detection for high sensitivity. The detection limits for uranium and plutonium will be in the range of 10^7 atoms (several femtograms).
● preparation of reference or control samples for internal quality control and quality assurance of measurements performed in Member State laboratories.
● preparation and certification of the cleanliness of sampling materials such as bottles, bags, or swipe media.

The design should also allow room for expansion and the implementation of other in-

Proposed layout of the clean laboratory



strumental techniques, including scanning electron microscopy with electron probe attachment for the detection and measurement of microscopic particles and inductively-coupled plasma mass spectrometry for the measurement of trace elements in liquid samples at the parts-per-billion level.

The proposed physical layout of the clean laboratory includes four separate Class-100 chemistry laboratories equipped with laminar-flow fume cupboards where the dissolution or ashing of samples can be performed. *(See figure.)* Each laboratory will handle a different type of sample (water, soil/sediment, biota or swipes) to avoid cross-contamination problems. These laboratories must be maintained at the highest level of cleanliness because the samples are handled in the open and are most vulnerable to contamination.

Additional rooms are provided for the instrumental measurements by radiometric methods (alpha, gamma, or X-ray spectrometry) or mass spectrometry. These laboratories can be operated at a more modest level of cleanliness by using clean-air showers over the most sensitive areas. Samples will enter the clean laboratory through a special room where the outer packaging can be removed and replaced with clean materials. Also important will be a laboratory for the cleaning of glassware and equipment and the purification of chemical reagents by sub-boiling distillation. Archival storage of samples will be performed in a separate room equipped with freezers for the preservation of biological samples.

Financial and administrative challenges

The first consideration for the establishment of a new facility is the funding. The IAEA has already received an extrabudgetary contribution from the United States of $1 000 000 for the clean laboratory. Preliminary estimates have been solicited and received for the construction of a new building within the Seibersdorf Research Centre complex. The clean laboratory itself will take the form of modular rooms constructed of pre-fabricated wall and ceiling panels. The ceiling panels would contain the filters and ventilation fans required to supply air of Class-100 quality into the modules. The estimated cost of such modules for the working design would be US $200 000 to $300 000, with an additional cost of US $600 000 for the inlet air handling system (heating/cooling/humidity control and pre-filtering).

The analytical instrumentation to be installed in the clean laboratory represents another significant investment; the thermal ionization mass spectrometer has already been ordered using US $500 000 from the IAEA's regular budget, but the radiometric instrumentation remains to be purchased. Instruments such as the scanning electron microscope or inductively-coupled mass spectrometer would cost between US $300 000 and $500 000 each, which Member States have been invited to provide through additional extrabudgetary contributions.

The operation of the clean laboratory will involve certain running costs, including utilities, supplies, and replacement of equipment and, of course, staff salaries. Present plans call for a staff consisting of two professionals, two laboratory technicians, and one maintenance worker. The laboratory technicians will require extensive training in general practices for a clean laboratory and in the specific chemical or analytical procedures that will be applied.

The construction of the building to house the clean laboratory is expected to take 12 months, with the installation of the clean modules themselves requiring about 3 months. It is planned that the laboratory's operation would begin by late 1995. The overall management of this project is carried out by a high-level committee chaired by Mr. Bruno Pellaud, Deputy Director General for Safeguards, with representatives of the Department of Research and Isotopes and the Department of Administration. The daily supervision of the work is being handled by a task force of staff members from the three departments.

Reinforcing analytical capabilities

At a time when governments are seeking greater confidence in the absence of undeclared nuclear activities, the techniques of environmental monitoring are being seen as one valuable verification tool.

The IAEA's establishment of a clean laboratory for analyzing environmental samples thus responds to an important need. Although the IAEA's existing facilities provide a valuable resource, they do not include the extensive capabilities that are needed for the type of environmental analysis required for safeguards applications. Once in operation, the clean laboratory promises to play a central role in the IAEA's continuing development of its verification system. ❐